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The LIMITS of SCIENTIFIC INQUIRY.

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I. GENERALITIES AND DEFINITIONS.

It is a peculiarity of natural science that its most surprising revelations are to be found in quarters where they are often least suspected, and even the most dissimilar departments of inquiry are so interlinked, so closely connected by invisible threads, as it were, that it is almost a matter of indifference what object we take in hand, whether a butterfly, or the first pebble we come across; a piece of chalk, or a piece of charcoal; a meteorite, or a star-fish, we shall find a sermon in it. We shall find—if we carry our inquiry far enough—that the butterfly and the pebble are not so very different in kind after all; that there is more than a superficial connection between a piece of chalk and one of charcoal, and that even such dissimilar things as meteorites and star-fishes show points of analogy where we may have least expected them.

We are living in a world of mystery. We are surrounded by appearances which we fondly persuade ourselves to be realities, having from infancy been accustomed to look upon them as such, though they are little more than phantoms of our imagination, or, as Carlyle aptly expressed it, the clothes in which we dress our ideas. On the other hand, there are a number of phenomena which, by reason of their very grandeur, should inspire us with awe, and give us food for unceasing reflection. We see the sun rise in the east and set in the west, and look upon this as the most natural thing in the world; we see the moon with its changes, and all the starry host—shooting-stars, and now and then a comet, and habit has rendered us indifferent to these phenomena. We drop a stone and expect it to fall upon the ground, we plant an acorn and expect an oak-tree from it: we would be greatly surprised, indeed, to see it develop into

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a cucumber; we perceive the effects of heat and cold upon ourselves and other bodies, and look upon all these things as matters of course—yet they are profound and awful mysteries if we look below the surface.

Carlyle, in his *Sartor Resartus*, gives utterance to the following remarkable sentence: "I stretch forth my hand to clutch the sun. Vain and foolish attempt! It is 100,000,000 miles distant. Yet, if by some wondrous miracle, my arm were to extend, of a sudden, so that I could touch it, the marvel would merely consist in the sudden lengthening of my arm, and in the power of my body to sustain it: it would be incomparably smaller than the marvel that I am here and have an arm which I can stretch forth at all."

We are surrounded by mysteries. Our existence itself is a mystery, and in proportion as we recognize this fact, we become restless and dissatisfied. We experience an indescribable longing to solve these mighty problems, to grasp the why and how of things, to fathom the infinite—a yearning and striving which not seldom becomes a burning desire, and develops into an all-absorbing passion. This feeling exists, it is real, and is implanted, I venture to say, in every human heart, although the majority may be unconscious of it. It manifests itself not only in the speculations of the philosopher, but in the general thirst for knowledge—in the curiosity of women as well as in the inquisitiveness of children. This universal longing for the unknown, this insatiable desire to ascertain facts and draw conclusions: what is it but our innate tendency to solve the riddle of existence, which seems to be the common inheritance of mankind?

The riddle of existence has not been, and probably never will be, completely solved, although it would be an unwarrantable dogmatical assertion to pronounce as absolutely impossible so gigantic a triumph of the human mind. But it may comfort us to know that we are at last marching in the right direction. We are no longer groping blindly in the dark, and, though we may never reach the goal, yet we can approach it. We can approach that glorious goal,

and we are approaching it. Our progress during the last 100 years is not merely visible, it is vast. It is marked by a succession of the most wonderful discoveries, of marvellous truths, which have flashed upon us; which have widened our horizon beyond the wildest dreams of eighteenth-century philosophers, and there is every indication that this progress will continue in a geometrical ratio.

2. THE OLD AND NEW PHILOSOPHY.

Our methods of inquiry differ vastly, if not totally from those of old, from those pursued by the old-world philosophers, with few exceptions, from Plato to Descartes. We take nothing for granted. We do not raise our fabric on a dogmatical assumption however seductively it may allure us. We draw our conclusions from experience, from facts which may be tested and verified at any moment: we require no belief, and we scorn to appeal to unreasoning "faith" of any description.

The difference between the old and new method is this: The inquirers and philosophers of the past imagined that they could arrive at the truth by a mere process of reasoning, independent of the phenomena of nature which surrounded them. They based their ingenious structures on the monstrous assumption that thought or mind existed altogether distinct from matter, that mind and matter were two separate existences, which have nothing whatever in common. They believed that by mere mental efforts they could solve the secrets of the universe, independent of matter, its laws and properties. Hence a science in our sense was, with them, impossible. They treated the phenomena of nature with indifference, nay with undisguised contempt, as unworthy of their notice, they relied solely on the "mind" to account for all that is hidden. Thus all the systems which they compiled, based on this rotten foundation, however ingenious in themselves, are monstrous absurdities, quite astounding and amusing if examined in the light of modern science. They are interesting only in so far as they afford an appalling example of misdirected and lost energy, and by warning us to avoid the rocks on which they grounded.

We have abandoned this hopeless dominion; we have struck out a road for ourselves. We do not believe that mind and matter are separate existences—in fact, we do not "believe" anything. To us the word "belief" is devoid of meaning; we either know or are in a state of agnosis. We have strong grounds for assuming that what is called "mind" is only a property of matter, just as elasticity, expansibility and gravity are properties of matter, and it is to matter that we are looking for redemption. We do not analyze and dissect the mind, we analyze and dissect matter. The modern philosopher studies physiology before he ventures an opinion on psychology: witness Herbert Spencer.

We observe the laws and phenomena of nature, we investigate the character of the objects which surround us and draw from them our conclusions. We know and recognize no other guide. If our deductions are hostile to theology the hostility is not intentional on our part, inasmuch as it is not, from the outset, our motive to destroy religious beliefs. If our labors should tend to do so, we can only shrug our shoulders. We want to proclaim the truth, quite irrespective of the consequences; we have nothing whatever to do with this subject in the prosecution of our task, we leave it entirely alone. To say, for instance, there is no creator, is in our eyes quite as dogmatical as to say there is one, but we decline to resort to the supposition of a deity in order to account for those mysteries which have, as yet, eluded our grasp. If, in order to account for the origin of a world, the disciple of religion points to a deity we only remind him that by doing so he explains nothing. He only substitutes a greater mystery for one already appalling in its magnitude. He reminds us of the Hindoo fable in reference to the "foundations of the universe," expressed in stone on every Hindoo temple. We there behold the figure of an elephant, carrying on its back a huge disc, which represents the world. The elephant, again, is supported by a still more gigantic tortoise. The speculative Hindoo is not so much interested in the question of the world's creation as in the problem of its foundation or support.

"What does the world rest on?" we ask a Brahmin.

"An elephant."

"And the elephant?"

"On a tortoise."

"And the tortoise?"

"That supports itself; it rests on nothing."

Supports itself? rests on nothing? Would it not have been much simpler to make the world self-supporting at once? Why introduce the elephant and the tortoise? They explain nothing; on the contrary, they only increase the world's weight and our difficulty.

Modern science discards every species of dogma and ignores every kind of supernatural intervention. Modern science is not conservative and pedantic, it is progressive and courts publicity; it is open to all and offers the purest and noblest pleasures, while it elevates the mind and makes veritable kings of its disciples.

3. THE GROWTH OF SCIENTIFIC KNOWLEDGE.

Geology is one of the most charming of the natural sciences, but, at the same time, it is one of the most difficult, because it involves questions and problems of the most varied and complicated character. Extensive preliminary studies in the departments of mineralogy, chemistry, physics and even astronomy are necessary before a broad general conception of this great science can be acquired by the student. There was a time—less than fifty years ago—when even great and wealthy colleges employed only one man to teach the whole of the natural sciences. To be sure they always had their full complement of historians, theologians, professors of literature, and, above all things, a complete set of philologists to take care of those very tremendous subjects, Greek and Latin. They were very expensive, these "classical" languages, but then they possessed the advantage of being comparatively useless which in itself was sufficient to insure them the highest esteem of the average university-regent.

The natural sciences were relegated to one man, generally poorly paid, who was styled "Professor of Natural Science,"

and who was expected to teach, and know all about, physics, chemistry, astronomy, geology, biology; in short, everything which comes within the scope of natural science. At the present day each of these subjects, and a dozen others, forms a distinct and separate study, and the labors of an army of indefatigable workers in each have already resulted in the accumulation of an amount of scientific literature, the mastering of which even in its most essential features, taxes the endurance of the most persevering.

To-day we have no professors of natural science at our large colleges, but we have professors of astronomy, of geology, of mineralogy, of chemistry, physics, etc., for each of these subdivisions has grown into a great science for itself, which requires the study of a life-time. The science of geology alone has assumed such vast proportions that no ordinary intellect can master it in all its bearings. Thus we now have palæontologists, men who devote themselves entirely to the study of fossils, mineralogists who inquire into the forms and properties of minerals, and petrographers who examine into the structure of rock-masses, and each of these specialties is capable of still further subdivision, and where it will end is more than I dare conjecture. If we go to any of our great colleges we shall find that the professor of botany, for instance, knows comparatively little beyond his own specialty; his knowledge of the other departments of natural science is sometimes not much better than that of the average school-boy's. It is sad that it should be so, but it is the inevitable consequence of the growth of knowledge. We can no more expect a professor of botany to know all about geology, chemistry, or natural philosophy, than we can expect a pint measure to hold a bushel. These men are the intellectual hewers of wood and drawers of water, the compilers of raw material, and it happens only once or twice in a century that a master-mind appears, like Laplace or Isaac Newton, like Darwin or Herbert Spencer, who surveys the whole gigantic field, like some general, who connects the accumulated facts and links them, and traces a wonderful law, of which no one had dreamed, which is listened to by mankind with bated breath, and received as a new and glorious revelation.

4. GEOLOGICAL PARADOXES.

We will now endeavor to present or discuss one or two problems in reference to the structure of our earth, or better, perhaps, in reference to the condition of the earth's interior, which may be new to many, and which, if they are not altogether new to those who have studied geology in its broader aspects, in connection with astronomy, physics and chemistry, will at least interest them in so far as the writer may succeed in giving an explanation of certain phenomena which have not as yet, to his knowledge, been accounted for in popular language. Besides, it may be presumed that an object looks different according to the direction in which we view it; and the greater the number of these directions, and the more varied the points of view the more perfect and accurate will be our impression of the size, shape and character of that object.

This globe, our earth, which we inhabit, and which revolves once in twenty-four hours around its axis, while pursuing at the same time its great course around the sun, and onward with the entire solar system towards an unknown region of space—probably around some still greater centre of attraction—this earth of ours has a diameter of about 8,000 miles. We live on its surface, on the surface of its outer crust, as it has been termed. We are tolerably well acquainted with this surface; we have travelled nearly all over it and have explored it in every direction, even though the highest polar regions and some parts of Central Africa are still unknown to us. We know that about three parts consist of water, in the shape of oceans and seas, and one part of what we are accustomed to call land. We find on this land mountains and valleys, and strange configurations, we find it rising from the ocean level, higher and higher, until it reaches in the loftiest summits with which we are acquainted an elevation of nearly 30,000 feet. We find this land, on the other hand, depressed in certain localities, depressed hundreds of feet below the sea-level (the dry land, of course; the coast of the Black Sea is about 200 feet beneath the level of the Mediterranean and the shore of the Dead Sea, 1,000 feet lower still). We have bored and dug

into it to a depth of some thousands of feet, yet our acquaintance with this terrestrial globe is but an exceedingly slight one; it only extends to a most insignificant portion of its outer crust. What are the highest mountains and what are the deepest borings, compared with the enormous bulk of our planet; what is 30,000 feet; what is 100,000 feet, compared with the radius of 4,000 miles? The loftiest Himalaya peaks, if contrasted with the diameter of the earth are but as the little protuberances on the skin of an orange, or the tiny granules on an egg-shell, and if we were to represent the Himalaya range on a globe a foot in diameter a few grains of rice, placed side by side, would furnish more than all the height required.

What is the character of that unknown interior? What kind of materials are hidden in these immense regions below and concealed from our sight forever? This is one of the fundamental problems of geology, a problem which has occupied the minds, not only of geologists but of physicians and astronomers for more than a century. We cannot get at those substances of our earth's interior which are more than a mile or two removed from the surface, and shall probably never be able to ascertain their condition by direct observation; yet we know that these substances must be quite different from those which we find at the surface, viz: in the insignificant portion of the outer crust, which we have been able to explore. It has been found that the average density of the earth is a little over five and a half, in other words the earth weighs about five and a half times as much as a globe of the same size, but consisting of water, would weigh. Now, it is certainly curious that the average gravity of the crust—so far as we have been able to explore it—is only two and a half; all the different kinds of sedimentary, metamorphic and eruptive rocks, minerals, fossils, etc., in short, all the materials of which the outer crust is composed weigh, on an average, only two and a half times as much as water. We are thus driven to the conclusion that the interior of the earth is composed of substances which have more than twice the density of those which constitute the outer crust. So far, we are not dealing

with anything in the nature of a theory or mere speculation, but with facts which can be as clearly proved as that twice two are four.

Now, in order to account for this enormous weight or high specific gravity of the earth, it has been assumed—and there is not now, perhaps, a single progressive geologist who doubts it—that during the gradual cooling or condensation of our globe the heavier substances gravitated towards the centre, and that the others were deposited around these according to their various densities. We are now acquainted with about seventy different fundamental substances or "elements," among which iridium is possessed of the highest specific gravity (weighs twenty-two times more than its bulk of water, thus a little more even than platinum). Now, provided there are not elements still heavier in the vastnesses below, which is extremely probable, we may consider the structure of our planet as that of a series of concentric shells, with a nucleus of iridium. This nucleus may have a diameter of from fifty to 200 miles, it is surrounded by a layer of platinum, followed by gold, lead, silver, copper, iron, etc.—the various metals according to their specific gravity—and finally the lighter elements, such as aluminium, silicon, magnesium and calcium (the latter one of the lightest, its gravity being only one and a half). We may, indeed, safely conclude that this succession of concentric layers, or shell-structure, is the structure of this terrestrial globe, viz: that the various materials are arranged or deposited according to their densities, and it would seem as if the greater part of the earth's interior—the thickest of all the shells—consisted of metallic iron. (It will be readily understood why most, if not all the metallic elements, which constitute the inner shells, must exist in a pure metallic state, if we bear in mind that oxygen, as one of the lightest elements, can only exist on or near the surface, and can only there undergo its combinations.)

It was formerly believed that the earth's interior was in a molten condition, that our planet was, so to speak, a drop of fiery liquid, surrounded by a comparatively thin crust, and the numerous volcanoes, which we find in or on this

crust, were looked upon as the chimneys of the huge inferno, or as safety-valves for letting out steam and other superfluous products. This absurd theory—absurd in the light of modern science—has been abandoned by every philosophical inquirer of the present, and is only retained by a few geologists of the old school, who have written bulky volumes thirty or forty years ago, full of dogmatical assertions, from which—for reasons best known to themselves—they cannot now well depart: men who, during the last thirty years, have neither learned nor forgotten anything, who have not progressed a single inch and still expect to live on the fame which they acquired at the time of our grandfathers, when it was far easier to establish a reputation in science than now.

We can now show, by an overwhelming array of incontrovertible arguments, that the earth must be solid to the very core. We are driven to infer this from the enormous gravity of our planet, from its small diameter, from the necessary increase of pressure towards the centre and from numerous other data. Besides, it has been experimentally demonstrated that when a globular molten mass is allowed to cool the solidification invariably commences at the centre and advances toward the periphery, a fact which had been theoretically established by mathematicians and physicist long before the experiments were undertaken. The lavas and other eruptive products ejected by volcanoes have nothing whatever to do with the earth's interior—with that greater interior which here concerns us—they are derived from an insignificant depth in the crust and are only local phenomena, which will be explained later on.

But here we are confronted by a most remarkable paradox. If we dig down, or bore into, the earth's crust no matter where—we observe an increase of temperature which averages 1° (Centigrade) for every ninety feet. Thus if we go down 180 feet we have 2° more than at the surface, if we go three times ninety, 3° more, etc. The regularity and constancy of this increase of temperature in proportion to the depth is quite astonishing and down to the greatest depth which has, as yet, been reached by boring or mining this law has been

found to prevail. In all the deeper mines, as, for instance, many coal mines in England, Wales and on the continent of Europe, as well as some of the silver mines of Nevada and California the heat is so unbearable that the workers have to be relieved after short intervals.

Now, if this increase of temperature continues at the same rate towards the earth's centre, which cannot well be doubted, then at a depth of less than five miles the heat must already be beyond that of the boiling-point of water, at thirty miles depth every known rock must exist in a state of fusion, at fifty miles even platinum, a metal which we can only melt with the greatest difficulty; at a depth of 200 miles we would have such a fabulous temperature that every known substance could only exist in a most attenuated state, as a gas, and what the condition of matter may be at 2,000 miles depth is more than we dare even hint at; it may be presumed, however, that the explorer would run no risk of catching cold there and that he would get along well without an overcoat.

But how can we reconcile this with the limited diameter and the enormous gravity of our planet? With this gradual increase of temperature the materials, instead of becoming denser and heavier, should become lighter, more and more attenuated or gaseous, in proportion as we approach the central region. This would necessitate a far greater diameter of our globe, a diameter which should extend beyond the moon's orbit, a diameter of at least 500,000, instead of 8,000 miles.

This very remarkable apparent incongruity has been a great puzzle to geologists and physicists, and it was only a few years ago that the mystery was solved in so thorough and simple a manner that many have not yet quite recovered from their astonishment, or rather from mortification in contemplating their previous blindness.

We know that the melting-point, boiling-point or temperature under which any given substance will assume the gaseous state, is determined by the pressure exerted upon it, either by the atmosphere or by any other body. Water, for instance, boils at 100° (Centigrade), but if we ascend

a mountain and heat it there, it will boil earlier, viz: it will require less than 100° of heat to make it boil, and the higher we go the more quickly ebullition will ensue. What is the cause of this?

The atmospheric pressure is less. All the air beneath us—perhaps a stratum a mile or more in thickness—no longer presses on the water, which on that account, can expand and evaporate more readily. On the summit of Mt. Blanc, for instance, water will boil already at 85° (instead of 100°). If we wanted to boil an egg there, we might keep on boiling it for hours, days, years or centuries and it would never be done, because at 85°, the albumen does not coagulate. In proportion as the atmospheric pressure diminishes the boiling-point of water is lowered, and here we have a ready means for determining the heights of mountains. All that is required is a test-tube, a spirit-lamp and a thermometer. A little water is boiled, then, by dipping the thermometer and noting how high the quicksilver column rises, the observer knows at once the approximate altitude. On the Plateau of Peru—perhaps the highest habitable region of our globe—no kind of food can be prepared by means of boiling. We could not cook an egg there, to say nothing of such things as potatoes, rice, peas, etc., neither soups nor stews are possible, the meat would remain almost raw in the water, and if we were to boil it for weeks in succession. Now if, on the other hand, we were to heat water below the level of the ocean, say in a deep mine, it would, of course, require a greater temperature than 100° to cause it to boil, and if we were to enclose it in a cylinder and exert upon it an artificial pressure of several atmospheres, we might expose it to a temperature which would suffice to melt iron, without reaching the boiling-point.

It will now readily be understood why the huge mass of our planet, in spite of the increasing temperature as we approach the centre, must be firm and solid throughout. The heat, of course, increases 1° per ninety feet of depth, but the pressure of each ninety-feet stratum increases in still greater proportion and more than counteracts the

tendency to melt, boil or evaporate, on the part of the materials involved.

Now, if it should happen in the neighborhood of the surface, for lower down it is quite inconceivable that the pressure exerted upon the rock-masses (and which alone prevents them from melting, boiling or flying into space) is temporarily relieved, lightened or removed, in consequence of local disturbances, such as shiftings of strata, denudations, etc., then a certain region which, perhaps, occupied several cubic miles, may be almost instantaneously transformed into a volcanic reservoir. The previously solid mass will be changed into liquid lava which, of course, requires more room and forces its way upwards, causing earthquakes, volcanic outbursts and similar phenomena. The extinct volcanoes along the Rhine, in the Auvergne and at innumerable other regions of the earth's crust, indicate the former existence of such subterranean reservoirs, caused by a release of pressure, in consequence of local disturbances and volcanic regions of this kind may originate at any time and at any place. Such a reservoir requires centuries, or thousands of years, to cool again, as lava is a bad conductor of heat, but ultimately solidification must ensue.

If the vast bulk of our earth's interior were in a molten condition we might naturally expect that the lavas ejected by the numerous volcanoes would exhibit a general uniformity in structure and composition. Instead of this they present the greatest differences, which can only be accounted for by attributing to them a local origin. Thus the lava ejected by Mt. Chimborazo, in the Cordilleras, is a dense black substance, resembling basalt, while Mt. Cotopaxi, which is only a few miles distant, throws out a light porous pumice-stone. Moreover, the specific gravity of the lavas never exceeds three, thus they can only represent regions of the uppermost crust of our planet.

5. IMMORTALITY IN THE LIGHT OF MODERN DYNAMICS.

The hypothesis in reference to the inevitable re-grouping of atoms, in accordance with the calculus of permutations, which I announced in conclusion of my lecture on

"Geological and Cosmical Problems," before the Franklin Institute, on November 17, 1890, is not entirely new, and I am bound to say that in at least one of its aspects it was advanced more than a hundred years ago by the great German philosopher, Leibnitz, at a time when the sciences of chemistry and physics were not sufficiently advanced to warrant such a speculation. In the light of modern dynamics, however, it deserves our closest attention, for if it can be shown that matter is composed of ultimate particles, call them atoms, centres of forces, or what we like, which are indestructible and in a state of continual vibration, I do not see how we can escape the conclusions which are forced upon us by this hypothesis. Some of the points which I am now about to discuss are new and I am not aware that this entire subject has ever been presented in the manner in which I now propose to deal with it.

According to the nebular hypothesis our earth, like all the rest of the planets, once existed in the shape of a gas-ring, which was thrown off, or became detached from, the sun during its process of condensation. This ring could not retain its form, it necessarily wentto pieces, and these afterwards collected into a single gas-globe, or spherical mass, which kept on pursuing its course around the great central body. The gaseous globe radiated an enormous amount of heat, it grew denser and denser, while its diameter diminished, it underwent an endless series of metamorphoses, until it finally became the earth as we know it, the planet which has given us birth. So far all this is nothing new.

Now, even if the nebular hyphothesis should prove erroneous the conclusions which I am now about to present will remain in force, for the same ultimate conclusions can be drawn from every other world-hypothesis which has, as yet, been advanced.

Every particle of our earth, every object, every substance which we now have upon or in our earth, must have already existed in that gaseous ring or primitive gas-globe, no matter in what form or condition; it was there. In that gas-globe were the particles which, after countless ages, became

united and roamed the great Mississippi valley in the shape of a mastodon, in that globe of gas were the atoms of carbon, which now constitute the table on which I am writing these lines, in that immense rotating sphere were the substances which are now united in the body of my humble self.

Could we but follow, in a few days or hours, the changes, the transformations, the endless pilgrimages, which the atoms and molecules of the substances had to undergo during those æons, before they became united so as to form, for instance, a human body, what marvels would we behold? The particles of hydrogen, carbon, phosphorus, etc., of which my body is composed, what a history might they not tell? In how many other bodies of the human species, of animals, plants and inorganic compounds may they not already have existed, separated, united, differently grouped or arranged? What may they not already have gone through and experienced? The reader will doubtless remember that famous church-yard scene in "Hamlet," in the fifth act, where *Hamlet* picks up a mouldering skull—the skull of poor *Yorick*—and addresses his friend *Horatio* thus:

Hamlet: To what base uses may we not return; why may not imagination trace the noble dust of Alexander till he finds it stopping a bung-hole?

Horatio: 'Twere to consider too curiously to consider so.

Hamlet: No, faith, not a jot, but to follow him thither with modesty enough and likelihood to lead it; as thus: Alexander died, Alexander was buried; Alexander returneth to dust; the dust is earth; of earth we make loam, and why of that loam whereto he was converted might they not stop a beer-barrel?

> "Imperious Cæsar, dead, and turned to clay,
> Might stop a hole to keep the wind away:
> O, that that earth, which kept the world in awe,
> Should patch a wall to expel the winter's flaw!"

If King Solomon, wise king though he was, really pronounced, or was the first to pronounce, the opinion that there is nothing new under the sun, he could not possibly have been aware of the enormous significance which attaches to this idea in the light of modern science. Why should not

the dust of Cæsar, which is now filling a bung-hole, why should not those atoms and molecules which, 2,000 years ago, were united in the body of Cæsar, why should they not, after endless transformations, endless changes, endless transitions, become again united in precisely the same manner; in other words, why should not the same Cæsar of whom we read in ancient history, reappear at a given time: in short, why should not everything now existing be compelled to undergo the same cycle of changes and reappear, not once, but an infinite number of times? It would be very strange if such were not the case. The following will illustrate this:

Supposing we were to take six dice, such as are used in the ordinary game. Let us place them in a little box, shake them and throw them on the table. We will assume that they had fallen so that each cube exhibited the number three on its upper face; of course, a rare chance. Now it can be mathematically shown after how many throws those six numbers are likely to reappear according to the law of chance. It is possible that they may turn up already with the next throw; on the other hand, we may have to cast those dice 10,000 times. Both cases are improbable; the probability lies in a certain number. If, instead of six dice, we were to take seven, the critical number is, of course, so much further removed, viz: it would be necessary to throw oftener to get the seven three's, and so the number of casts increases with every additional cube, till we finally obtain enormous figures. But no matter how many dice, the three's must turn up, if we can throw them long enough, and if, in the case of 1,000 dice, it were to take 1,000,000 years, the three's must appear and reappear again and again after proportionate intervals.

Supposing now that, instead of dice, we were to take a glass filled with sand. There are, let us assume, 20,000 sand grains in the glass. Each particular grain occupies a certain position, which is bound to differ from that of all the rest of the sand grains; this the reader will doubtless admit. We shake the glass; the positions are altered, the order of arrangement is disturbed. We shake it again; the sand

grains are now in a totally different position. We continue shaking the glass and the time must come when each individual grain again occupies the exact position which it occupied when we originally started. It is a mathematical necessity, which all will admit who know anything of the calculus of permutations. The 20,000 sand grains may be looked upon as so many dice, which are bound to fall precisely as they once fell if we can throw them sufficiently often.

Now, I have strong grounds for assuming that my body is composed of atoms, or groups of atoms, of a limited number of elementary substances, or of one elementary substance, if all matter has been evolved from one primary element. The number of these atoms may be ever so great, it has nothing whatever to do with the inevitable result. I know also that all other bodies are composed of such atoms, or groups of atoms (molecules), not only those of the human species, animals and plants, but of inorganic substances, rocks, metals, fluids, gases; in short, of everything which exists in, upon or above the ground in the atmosphere. I know, furthermore, that the atoms of even the hardest and seemingly most enduring substances, such as agate and diamond, are in a state of continual vibration, that nothing can permanently retain its form, that the entire universe always has been, is now, and always will be, in a state of metamorphosis or continual change.

The time must arrive when the atoms or molecules which are now united in my body, after countless transformations and wanderings through all kinds of bodies, substances or intermediary stages, will once more unite in the same manner; in other words, the time must arrive when my life, like that of every other individual, will repeat itself. Yes, repeat itself, and not merely once, but an infinite number of times.

And more than this. If one of my readers should imagine that the atoms or molecules, which now constitute his body, are thus associated for the first time, I can only admire his simplicity. There is nothing new under the sun. Those molecules were united in this manner before, and

before this again, and 100,000,000 times previously, as far as our imagination can carry us back into the abysmal night of the æons of the past. In other words: each of my readers has been, ages ago, what he is now, has lived and gone through all this before, has felt and experienced what he now feels and experiences, down to the minutest details, has opened his *Journal of the Franklin Institute* billions of years ago and read the same lines; not once, but an endless number of times. The recollection, of course, is lost. Life and mind itself, consciousness or "soul" is only a product of matter, and if the same substances reunite in the same manner, the same phenomena must inevitably recur.

Let the molecules which now constitute my body undergo ever so many metamorphoses, let them even—which, of course, is very improbable—once fill a bung-hole, let them be scattered about in all manner of forms and conditions, in close contact or millions of miles apart; they must come together again, may the thought please or distress me; this is the iron logic of modern dynamics.

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